REMARKS

In the April 19, 2006 communication, the Examiner requested the identification of support in the specification of the present application for the amendment made to claim 37. In response thereto, the Examiner's attention is directed towards page 7, lines 22-26 and page 8, lines 19-25 of the present application for support of the subject matter recited in pending claim 37.

Additionally, in the April 2006 communication, the Examiner requested the Applicant to acknowledge the Examiner's request for the identity of any co-pending application which claims subject matter similar to that recited in the pending claims of the present application. The Applicants hereby acknowledge the Examiner's request and state that they are not aware of any co-pending application which includes claims reciting similar subject matter to that presented in the present application. The Examiner's attention is nevertheless directed towards co-pending application USSN 10/449,499 which belongs to the family of applications including the present matter.

Additionally, in response to a request in the outstanding communication, the Applicants submit herewith another copy of the article entitled "Heat Treatment of Steel." Accordingly, it is believed that the enclosed article can now be properly considered and made of record.

Respectfully submitted,
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Heat Treatment of Steel

From the 1924 edition of Machinery's Handbook
This is section 3 of 7

Two of the illustrations have been traced in SuperPaint and the rest are as scanned. They looked better in the book.

DISCLAIMER: DON'T WRITE FOR ADVICE ON THIS STUFF. I DON'T HAVE ANY.

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Hardening

Critical Temperatures. -- The "critical points" of carbon tool steel are the temperatures at which certain changes in the chemical composition of the steel take place, during both heating and cooling. Steel at normal temperatures has its carbon (which is the chief hardening element) in a certain form called *pearlite* carbon, and if the steel is heated to a certain temperature, a change occurs and the pearlite becomes *martensite* or hardening carbon. If the steel is allowed to cool slowly, the hardening carbon changes back to pearlite. The points at which these changes occur are the decalescence and recalescence or critical points, and the effect of these molecular changes is as follows: When a piece of steel is heated to a certain point, it continues to absorb heat without appreciably rising in temperature, although its immediate surroundings may be hotter than the steel. This is the *decalescence* point. Similarly, steel cooling slowly from a high heat will, at a certain temperature, actually increase in temperature, although its surroundings may be colder. This takes place at the *recalescence* point. The recalescence point is lower than the decalescence point by anywhere from 85 to 215 degrees F., and the lower of these points does not manifest itself unless the higher one has first been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, so that the pearlite carbon is changed into a hardening carbon, no hardening action can take place; and unless the steel is cooled suddenly before it reaches the recalescence point, thus preventing the changing back again from hardening to pearlite carbon, no hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures when hardening.

Determining Hardening Temperatures. -- The temperatures at which decalescence occurs vary with the amount of carbon in the steel, and are also higher for high-speed steel than for ordinary crucible steel. The decalescence point of any steel marks the correct hardening temperature, and the steel should be removed from the source of heat as soon as is has been heated uniformly to this temperature. Heating the piece slightly above this point may be desirable, either to insure the structural change being complete throughout, or to allow for any slight loss of heat which may occur in transferring the work from the furnace to the quenching bath. When steel is heated above the temperature of decalescence, it is non-magnetic. If steel is heated to a bright red, it will have no attraction for a magnet or magnetic needle, but at about a "cherry-red," it regains its magnetic property. This phenomenon is sometimes taken advantage of for determining the correct hardening temperature, and the use of a magnet is to be recommended if a pyrometer is not available. The only point requiring judgment is the length of time the steel should

remain in the furnace after it has become non-magnetic, as the time varies with the size of the piece. When applying the magnetic needle test, be sure that the needle is not being attracted by the tongs.

The correct hardening temperature for any carbon steel can be determined accurately by the use of a pyrometer. A form of apparatus often used for testing specimens of steel consists of a small electric furnace in which to heat the specimen, and a special thermo-couple pyrometer (see "Pyrometers") for indicating the range of temperatures through which the steel passes. The pyrometer consists of a thermo-couple, connecting leads and an indicating meter. The thermo-couple is of small wire so as to respond readily to any slight temperature variation. When testing a piece of steel with this apparatus, the temperature indicated by the meter rises uniformly until the decalescence point is reached. At this temperature, the indicating pointer of the meter remains stationary, the added heat being consumed by internal changes. When these changes are completed, the temperature again rises, the length of the elapsed period depending upon the speed of heating. The temperature at which this pause in the motion of the indicating pointer occurs should be carefully noted. To obtain the lower critical point, the temperature is first raised about 100 degrees F. above the decalescence point; the steel is then removed from the furnace and is allowed to cool. The decrease of temperature is immediately shown by the fall of the meter pointer, and, at a temperature somewhat below the decalescence point, there is again a noticeable lag in the movement of the pointer. The temperature at which the movement ceases entirely is the recalescence point. Immediately following, there may occur a slight rising movement of the pointer. During these intervals of temperature lag, both during heating and cooling, there may occur a small fluctuation in temperature; hence, a definite point in each of these intervals should be considered when a test is made, both critical temperatures being taken at the time the pointer first becomes stationary.

While it is possible to harden steel within a temperature range of about 200 degrees and obtain what might seem to be good results, the best results are obtained within a very narrow range of temperatures which are close to the decalescence point. The hardening temperature for both low tungsten and carbon steel can be located with accuracy, and the complete change from soft to hard occurs within a range of 10 degrees F. or less. After the temperature has been increased more than from 35 to 55 degrees F. above the hardening point, the hardness of steel is lessened by a higher temperature, provided the heating is sufficiently prolonged for the steel to be thoroughly heated.

Hardening or Quenching Baths. -- When steel heated above the critical point is plunged into a cooling bath, the rapidity with which the heat is absorbed by the bath affects the degree of hardness; hence, baths of various kinds are used for different classes of work. Clear cold water is commonly employed and brine is sometimes substituted to increase the degree of hardness. Sperm [whale oil] and lard oil baths are used for hardening springs, and raw linseed oil is excellent for cutters and other small tools. The effect of a bath upon steel depends upon its composition, temperature, and volume. The bath should be amply large to dissipate the heat rapidly, and the temperature should be kept about constant, so that successive pieces will be cooled at the same rate. Greater hardness is obtained from quenching in salt brine, and less in oil, than is obtained by the use of water. This is due to the difference in the heat-dissipating qualities of these substances. When water is used, it should be "soft," as unsatisfactory results will be obtained with "hard" water. If thin pieces are plunged into brine, there is danger of cracking, owing to the suddenness of the cooling.

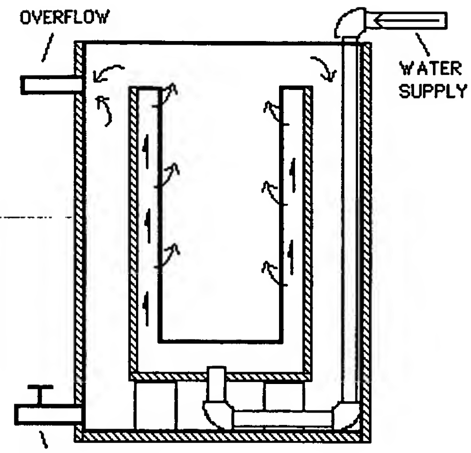
The temperature of the hardening bath has a great deal to do with the hardness obtained. In certain experiments a bar quenched at 41 degrees F. showed a scleroscopic hardness of 101. A piece from the same bar quenched at 75 degrees F. had a hardness of 96, while, when the temperature of the water was raised to 124 degrees F., the bar was decidedly soft, having a hardness of only 83. The higher the temperature of the quenching water, the more nearly does its effect approach that of oil, and if boiling water is used for quenching, it will have an effect even more gentle than that of oil; in fact, it would leave the steel nearly soft. With oil baths, the temperature changes have little effect on the degree of

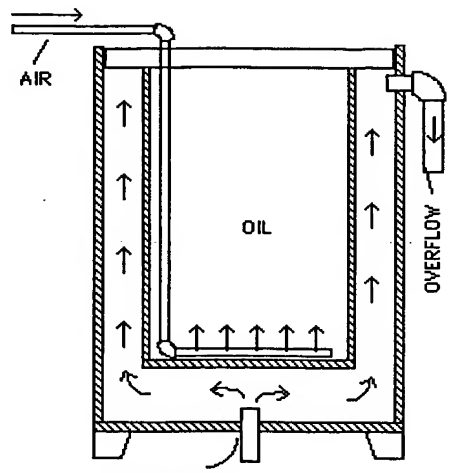
hardness. Parts of irregular shape are sometimes quenched in a water bath that has been warmed somewhat to prevent sudden cooling and cracking. A water bath having one or two inches of oil on top is sometimes employed to advantage for tools made of high-carbon steel, as the oil through which the work first passes reduces the sudden action of the water.

Irregularly shaped parts should be immersed so that the heaviest of thickest section enters the bath first. After immersion, the part to be hardened should be agitated in the bath; the agitation reduces the tendency of the formation of a vapor coating on certain surfaces, and a more uniform rate of cooling is obtained. The work should never be dropped to the bottom of the bath until quite cool. High-speed steel is cooled for hardening either by means of an air blast or an oil bath. Both fresh and salt water are also used, although, as a general rule, water should not be used for high-speed steel. Various oils, such as cotton-seed, linseed, lard, whale oil, kerosene, etc., are also employed; many prefer cotton-seed oil. Linseed has the objection of becoming gummy, and lard oil has a tendency to become rancid. Whale oil or fish oil give satisfactory results, but have offensive odors, although this can be overcome by the addition of about three per cent of heavy "tempering" oil.

A quenching solution of a 3 per cent sulphuric acid and 97 per cent of water will make hardened carbon steel tools come out of the quenching bath bright and clean. This bath is sometimes used for drills and reamers which are not to be polished in the flutes after hardening. Another method of cleaning drills and similar tools after hardening is to pickle them in a solution of 1 part hydrochloric acid and 9 parts water. Still another method is to use a heating bath consisting of 2 parts barium chloride and 3 parts potassium chloride. This method is satisfactory for reamers and tools which are not to be polished in the flutes after hardening.

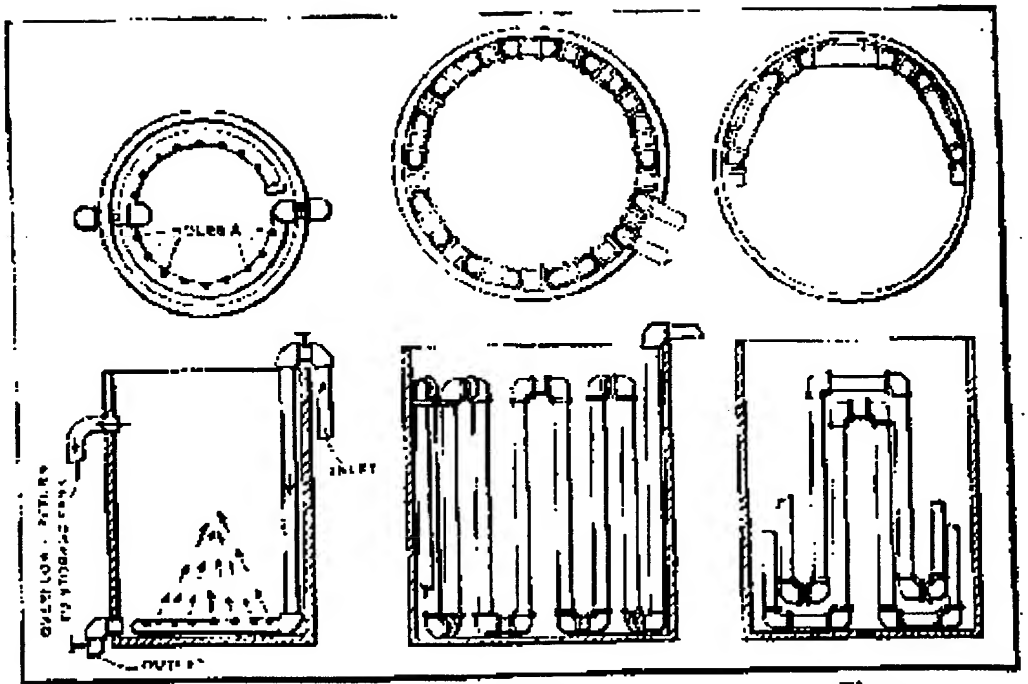
Oil Quenching Baths. -- Oil is used very extensively as a quenching medium as it gives the best proportion between hardness, toughness and warpage for standard steels. Special compounded oils of the soluble type are now used in many plants instead of such oils as fish oil, linseed oil, cotton-seed oil, etc. The soluble properties enable the oil to make an emulsion with water. A good quenching oil should possess a flash and fire point sufficiently high to be safe under the conditions used and 350 degrees F. should be about the minimum point. The specific heat of the oil regulates the hardness and toughness of the quenched steel, and the greater the specific heat, the harder the steel will be. Specific heats of quenching oils vary from 0.20 to 0.75, the specific heats of fish, animal, and vegetable oils usually being from 0.2 to 0.4, and of soluble and mineral oils, from 0.5 to 0.7. The oil should not contain water, gum when used, have a disagreeable odor or become rancid. A great many concerns use paraffin and mineral oils for quenching, while a few use crude fuel oils. The quantity of steel that can be quenched per gallon of oil depends on the fluidity of the oil, or its draining qualities. The so-called "refrigerating qualities" are really the capacity of the oil to remove the heat from the steel at a fast rate and then radiate its own heat to the atmosphere.





Tanks for Quenching Baths. -- The main point to be considered in a quenching bath is to keep it at a uniform temperature, so that each successive piece quenched will be subjected to the same heat. The next consideration is to keep the bath agitated, so that it will not be of different temperatures in different places; if thoroughly agitated and kept in motion, as is the case with the bath shown in Fig. 1, it is not even necessary to keep the pieces in motion in the bath, as steam will not be likely to form around the pieces quenched. Experience has proved that if a piece is held still in a thoroughly agitated bath, it will come out much straighter than if it has been moved around in an unagitated bath. This is an important consideration, especially when hardening long pieces. It is, besides, no easy matter to keep heavy and long pieces in motion unless it be done by mechanical means.

In Fig. 1 is shown a water or brine tank for quenching baths. Water is forced by a pump or other means through the supply tube into the intermediate space between the outer and inner tank. From the intermediate space it is forced into the inner tank through holes as indicated. The water returns to the storage tank by overflowing from the inner tank into the outer one and then through the overflow pipe as indicated. In Fig. 3 is shown another water or brine tank of a more common type. In this case the water or brine is pumped from the storage tank and continuously returned to it. If the storage tank contains a large volume of water, there is no need of a special means for cooling. Otherwise, arrangements must be made for cooling the water after it has passed through the tank. The bath is agitated by the force with which the water is pumped into it. The holes at *A* are drilled at an angle, so as to throw the water toward the center of the tank. In Fig. 2 is shown an oil quenching tank in which water is circulated in an outer surrounding tank for keeping the oil bath cool. Air is forced into the oil bath to keep it agitated. Fig. 6 shows a water and oil tank combined. The oil is kept cool by a coil passing through it in which water is circulated, which later passes into the water tank. The water and oil baths in this case are not agitated.



Illustrations: Fig. 3-4-5 Fig. 3 Fig. 4 Fig. 5

Fig. 4 shows the ordinary type of quenching tank cooled by water forced through a coil of pipe. This can be used for either oil, water or brine. Fig. 5 shows a similar type of quenching tank, but with two coils of pipe. Water flows through one of these and steam through the other. By this means it is possible to keep the bath at a constant temperature.

Hardening High-speed Steel. -- High-speed steel must be heated to a much higher temperature than carbon steel. A temperature of from 1400 degrees to 1600 degrees F. is sufficient for carbon steel; high-speed steel requires from 1800 degrees to 2200 degrees F. The usual method of hardening a high-speed steel tool, such as a turning or planing tool, is to heat the cutting end slowly to a temperature of about 1800 degrees F., and then more rapidly to about 2200 degrees F., or until the end is at a dazzling white heat and shows signs of melting down. The tool point is then cooled either by plunging it in a bath of oil (such as linseed or cotton-seed) or by placing the end in a blast of dry air. When an oil quenching bath is used, its temperature is varied from the room temperature to 350 degrees F., according to the steel used. The exact treatment varies for different steels and it is advisable to follow the directions given by the steel makers. High-speed steel parts that would be injured by a temperature high enough to melt the edges are hardened by heating slowly to as high a degree as possible and then cooling, as described. Formerly, the air blast was recommended by most steel makers, but oil is now extensively used. Care should be taken to quench the heated steel rapidly after removing from the source of heat. The barium-chloride bath has been used quite extensively for heating machine-finished, high-speed steel tools preparatory to hardening. The barium-chloride forms a thin coating on the steel, which is thus protected from oxidation while being transferred from the heating bath to the cooling bath. Tests have demonstrated, however, that barium-chloride baths have certain disadvantages for heating high-speed steel preparatory to hardening, because if the steel is heated to the required temperature, the surface of the tool is softened to some extent. These tests indicate that whenever this salt is used as a heating bath, the temperature should not be raised above 2050 degrees F. When about 0.010 inch is ground from the cutting edges of the tools, the influence of heating in barium chloride may be negligible. (See "Disadvantages of Barium-chloride Bath".)

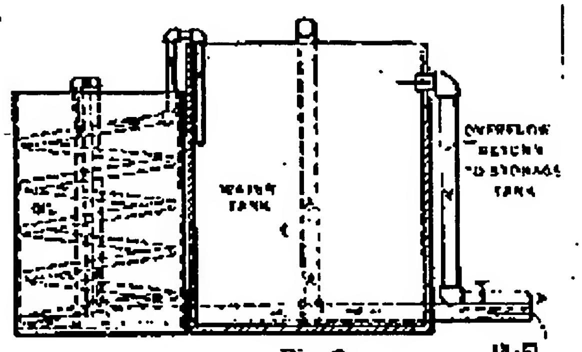


Fig.6

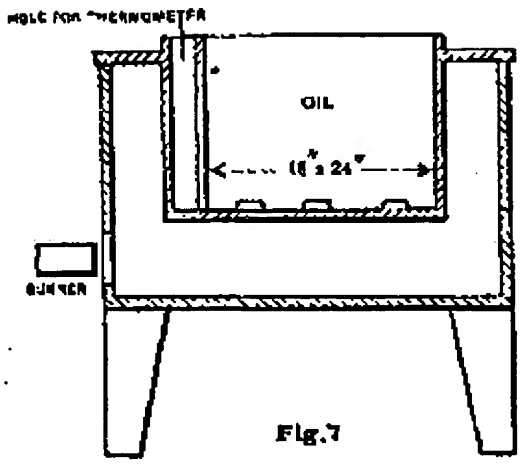


Fig.7

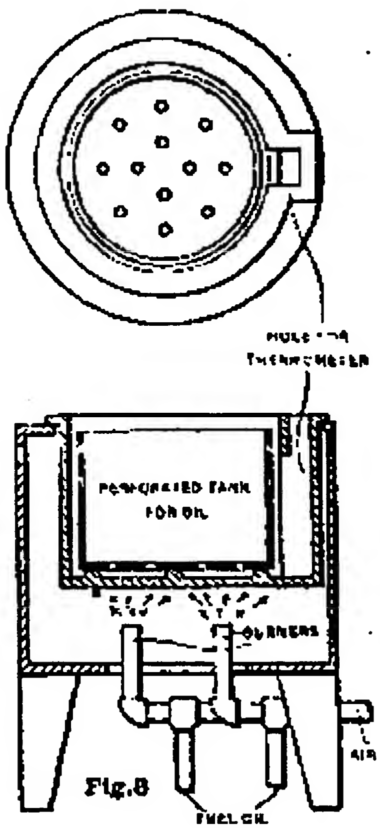


Fig.8

Very satisfactory results in hardening high-speed steel tools, such as cutters, drills, etc., have been obtained by the following method: First pre-heat in an oven-type gas furnace to from 1300 degrees to 1500 degrees F.; then transfer the steel to another gas furnace having a temperature varying from about 2000 degrees to 2200 degrees F.; when the steel has attained this temperature, quench in a metallic salt bath having a temperature varying from 600 degrees to 1200 degrees F., depending on the kind of high-speed steel used. The piece to be hardened should be stirred vigorously in the bath until it has obtained the temperature of the bath; then it is cooled, preferably in the air, and requires no further tempering; or it may be put directly into the tempering oil, which should be at a temperature anywhere between 100 and 600 degrees F. The tempering bath is then gradually raised to the heat required for tempering. The salt bath used for quenching should be calcium chloride, sodium chloride and potassium ferro-cyanide, in proportions depending upon the required heat. Various kinds of steel require different temperatures for the metallic salt bath. After the temper of the tool has been drawn in the oil, the work is dipped in a tank of caustic soda, and then in hot water. This will remove all oil which might adhere to the tools, and

is a method that applies to all tools after being tempered.

The Taylor-White Process. -- This process of hardening high-speed steel is, in brief, as follows: The first method, commonly known as the "high-heat treatment," is effected by heating the tool slowly to 1500 degrees F., and then rapidly from that temperature to just below the melting point, after which the tool is quickly cooled below 1550 degrees. At this point, the cooling is continued either fast or slow to the temperature of the air. It is important to avoid any increase of temperature during the cooling period. The second or "low-heat treatment" consists in re-heating a tool which has had the high-heat treatment to a temperature between 700 and 1240 degrees F., preferably in a lead bath, for a period of five minutes. The tool is then cooled to the temperature of the air either rapidly or slowly.

Heat-Treatment of Spring Steel. -- A number of experiments were made at the Baldwin Locomotive Works, to determine the effect of different heat-treatments on the transverse elastic limit and the modulus of elasticity of steels commonly used for locomotive springs. The points investigated were the effect of annealing, the comparative effect of quenching in water or oil, and the effect of re-heating the steel to various temperatures after complete cooling in water or oil. The steel used for the tests was basic open-hearth spring steel of the following composition: Carbon, 1.01 per cent; manganese, 0.38 per cent; phosphorus, 0.032 per cent; sulphur, 0.032 per cent; silicon, 0.13 per cent. This steel was found to reach its decalescence point at 1360 degrees F. Previous experiments had shown that, for annealing, it should be heated 40 degrees or 50 degrees above this temperature, and for hardening, from 50 degrees to 100 degrees above the point of decalescence. For the experiments, the following temperatures were used: For annealing, 1400 degrees F.; for quenching in oil, 1450 degrees F.; for quenching in water, 1425 degrees F. The results obtained are given in the table, "Results of Tests on Spring Steel".

As the table shows, the highest elastic limit obtainable, when heating to 1450 degrees and quenching in oil, was 187,400 pounds per square inch, which was obtained when the temper was not drawn after quenching. The higher the tempering temperature, the lower the elastic limit fell. When the steel was quenched at 1425 degrees F. in water, and the temper was not drawn, it was brittle and broke when deflected 0.175 inch. Drawing the temper to 600 degrees F., after hardening in water, gave an elastic limit of 219,800 pounds. When the temper was drawn to 1050 degrees F., the elastic limit dropped to 180,700 pounds, but the test piece did not break at 1.1 inch deflection. The tests show that the modulus of elasticity is practically constant, and apparently independent of heat-treatment. The conclusions are that steel of 1 per cent carbon, when quenched in cold water at its critical temperature or slightly above, is usually too hard and brittle for making springs or tools. The tests also show that the elastic limit of 1 per cent carbon steel can be made to vary from 78,500 to 240,800 pounds per square inch, by changes in the heat-treatment, and that very small changes in temperature when drawing the temper are sufficient to affect the elastic limit of the steel. Hence, to obtain good results, it is necessary to have means of heating the steel uniformly to the proper temperature, as well as cooling at the desired rate in a medium, the temperature and heat conductivity of which can be kept reasonably constant.

Results of Tests on Spring Steel

Hardened in		Drawn to, degrees F	Diam. Test Piece	Elastic Limit	Modulus of Elasticity	Moment of Inertia	Breakage Deflection*
Oil, degrees F	Water, degrees F						
1450		560	1.000	137,500	28,700,000	0.04909	
1450		500	1.000	160,400	27,150,000	0.04909	
1450		400	0.991	177,600	29,080,000	0.04730	
1450		not drawn	0.993	187,400	28,610,000	0.04772	

	1425	1050	0.997	180,700	28,070,000	0.04850	
	1425	900	0.998	233,900	28,860,000	0.04870	
	1425	750	0.994	240,800	29,220,000	0.04790	0.744
	1425	600	0.991	219,800	30,420,000	0.04736	0.175
	1425	not drawn	0.991	219,800	29,960,000	0.04730	0.175
Annealed in Lead at 1400 deg. F.			0.991	78,500	27,550,000	0.04730	

Local Hardening. -- One method of hardening locally is to cover the part that is to remain soft with a thin metal shield, so that it prevents the surface from being suddenly cooled by the direct action of the cooling medium. The steam or vapor which forms beneath the cover prevents the cooling medium from entering until the work has cooled sufficiently to prevent hardening; hence, a rather loose-fitting shield is desirable. The shield should be made of sheet iron or steel of about No. 29 gage (0.014 inch), for ordinary work. It is composed of one or more pieces, depending on the shape of the part, and, when several pieces are required, they can be bound together with wires or rivets. Of course, the surfaces to be hardened are left exposed. The heating should be done in a furnace or open-forge fire. A lead bath should not be used, because the hot lead beneath the shield will cause an explosion when the part is cooled. The quenching bath can be the same as when the shield is not used.

Local hardening is also effected by the application of a compound called "Enamelite" to the parts which are to remain soft. This compound, for tool steel, is in the form of a powder which is mixed with hot water to form a paste. It has the property of clinging to the steel and liberating hydrogen (the greatest known non-conductor) when the heated steel is plunged into the water. This causes the steel to retain its heat long enough to escape the chill, so that it remains soft where the enamelite has been applied.

Defects in Hardening. -- Uneven heating is the cause of most of the defects in hardening. Cracks of a circular form, from the corners or edges of a tool, indicate uneven heating in hardening. Cracks of a vertical nature and dark-colored fissures indicate that the steel has been burned and should be put on the scrap heap. Tools which have hard and soft places have been either unevenly heated, unevenly cooled, or "soaked", a term used to indicate prolonged heating. A tool not thoroughly moved about in the hardening fluid will show hard and soft places, and have a tendency to crack. Tools which are hardened simply by dropping them to the bottom of the tank, sometimes have soft places, owing to contact with the floor or sides of the tank. They should be thoroughly quenched before dropping. when a tool appears soft and will not harden, it probably has been decarbonized on the surface by too much heat or by soaking too long. The surface must be removed before the tool will harden properly. Tools are sometimes soft because the cooling bath is not large enough for the tools being hardened, and becomes too warm after a few pieces have been quenched.

Overheated Steel. -- Overheated steel that is not actually burned can be partly restored by heating to the proper heat, and allowing it to cool slowly in hot ashes or sand; when cold, the steel is hardened again at the proper hardening heat. Tools treated in this way are not as good as when treated at the proper heat throughout, but they are partially restored, and if the overheating originally took place in forging, the risk of cracking in hardening will be lessened by adopting the process mentioned. Care should be taken that the tuyere of the forge is well covered when heating tool steel; a tool coming in direct contact with the air blast will become surface burned, show soft places in hardening and wear badly in use.

Scale on Hardened Steel. -- The formation of scale on the surface of hardened steel is due to the contact of oxygen with the heated steel; hence, to prevent scale, the heated steel must not be exposed to the action of the air. When using an oven heating furnace, the flame should be so regulated that it is not

visible in the heating chamber. The heated steel should be exposed to the air as little as possible, when transferring it from the furnace to the quenching bath. An old method of preventing scale and retaining a fine finish on dies is as follows: Fill the die impression with powdered boracic acid and place near the fire until the acid melts; then add a little more acid to insure covering all the surfaces. The die is then hardened in the usual way. If the boracic acid does not come entirely off in the quenching bath, immerse the work in boiling water. Dies hardened by this method are said to be as durable as those heated without the acid. Detailed table of contents
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